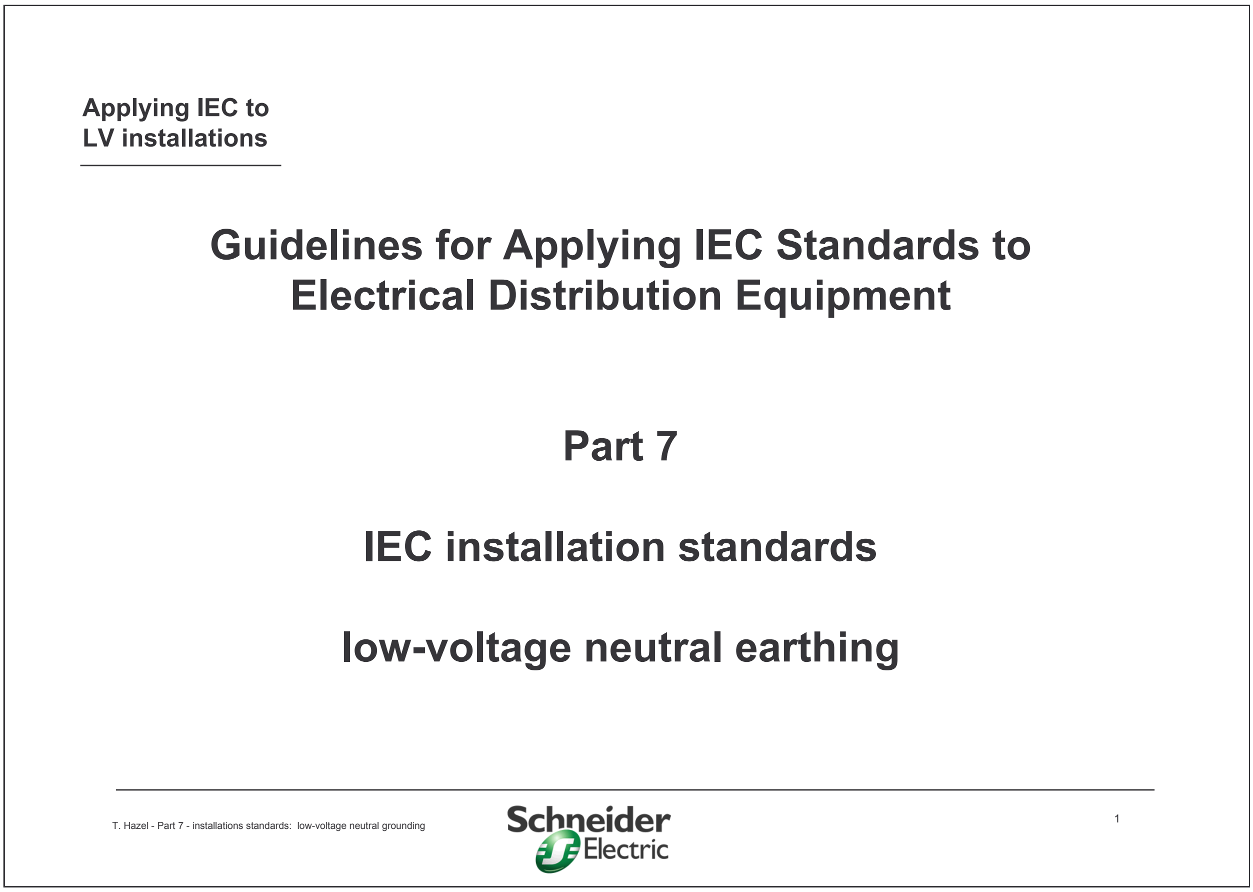


Applying IEC to
LV installations

Guidelines for Applying IEC Standards to Electrical Distribution Equipment

Part 7

IEC installation standards

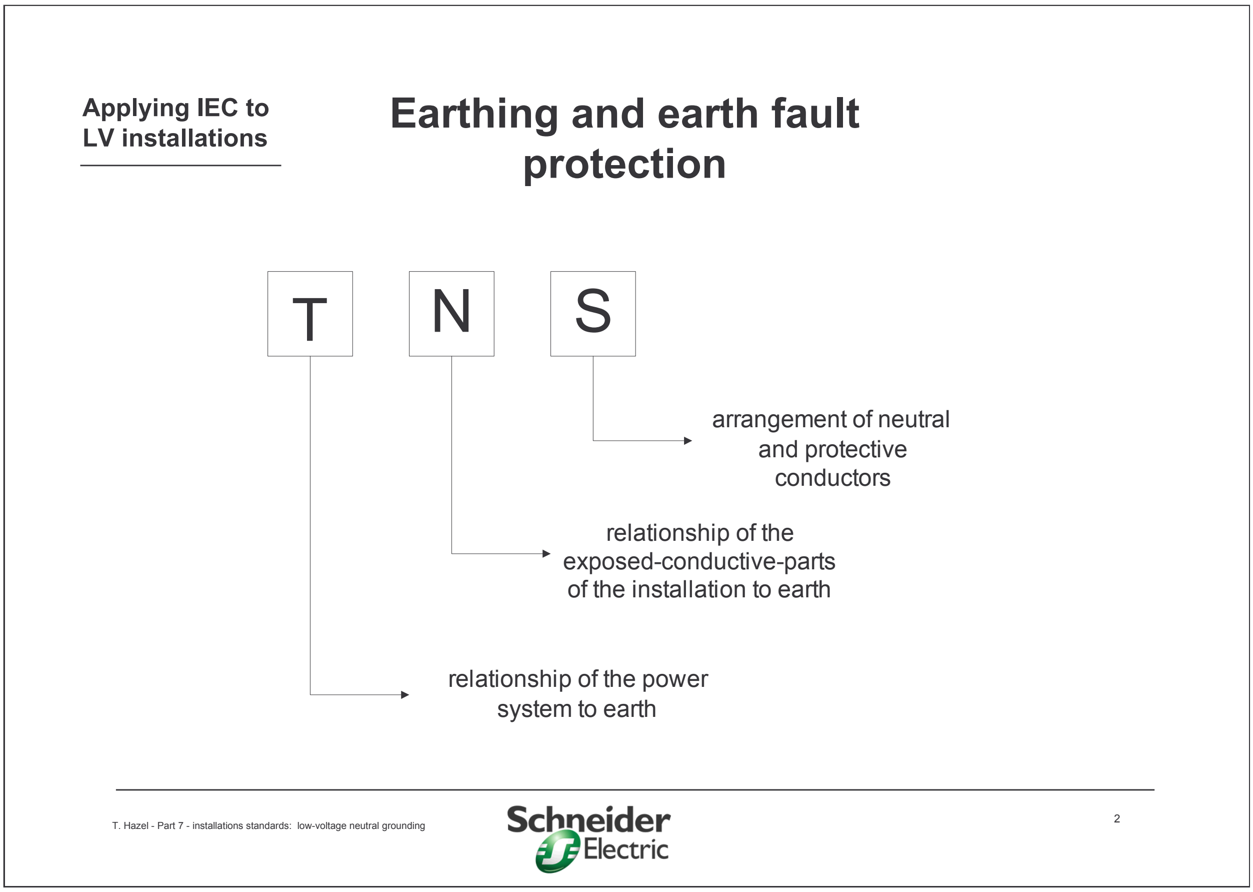
low-voltage neutral earthing

electrical installations

Installation standards deal with a system comprised of several different pieces of equipment. One subject of major importance in any electrical system is its earthing, even though this has no effect in the transmission of energy which is the raison d'être of the electrical distribution system. This subject is often misunderstood and misapplied even by engineers familiar with IEC standards. Earthing of low-voltage systems will be discussed in this part of the tutorial. The term *earthing* is used in this tutorial instead of *grounding* since this reflects IEC practice.

high-voltage installation standards

There are no IEC standards for high-voltage installations. Work is in progress in TC99 and voting should take place in the near future.



Applying IEC to LV installations

Earthing and earth fault protection

T
N
S
arrangement of neutral and protective conductors
relationship of the exposed-conductive-parts of the installation to earth
relationship of the power system to earth

earthing of low-voltage systems

IEC60364-3 electrical installations of buildings part 3 assessment of general characteristics defines the code used to specify the earthing of low-voltage distribution systems. The code consists of 2 letters and subsequent letter(s) if they are required. The definitions given hereafter refer to typical industrial applications.

earth fault protection

There is no requirement in IEC standards to implement earth fault protection on the incoming circuit-breaker to eliminate resistive earth faults. According to the above mentioned IEC standard, earth faults can be eliminated by means of phase protection or sensitive earth fault protection. Should earth fault protection be provided on the incoming circuit-breaker and phase protection be used on outgoing feeders, protection coordination is often not possible. This results in tripping the incoming circuit-breaker for earth faults on outgoing feeders which is normally unacceptable for industrial and commercial applications. If the application requires that earth fault protection be provided on incoming circuit-breakers, sensitive earth fault protection should also be provided on outgoing feeders to ensure selective tripping.

Applying IEC to LV installations

Neutral & exposed conductive part connections

First letter : power system to earth

- T direct connection of neutral to earth
- I neutral isolated or connected via impedance to earth

Second letter : conductive parts to earth

- T direct connection of exposed parts to earth
- N direct connection of exposed parts to neutral

The use of these letters is described in the following pages.

Applying IEC to LV installations

Arrangement of N & PE conductors

Subsequent letters (if any)

- S neutral and protective conductors separate (N & PE)
- C neutral and protective conductors combined (PEN)
- C-S TN-C near the source, TN-S near the loads

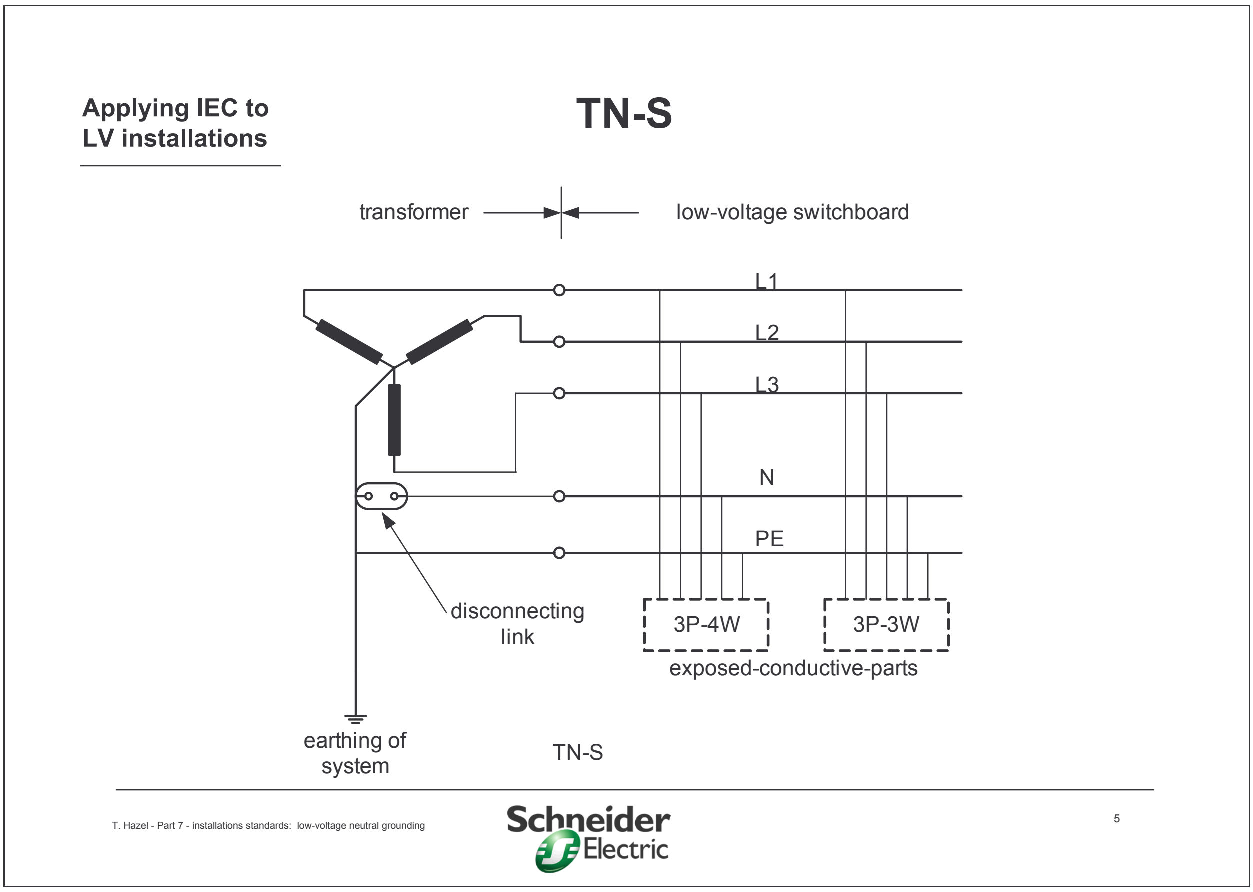
commonly used earthing systems

The IEC standards do not give guidelines related to the best choice of the earthing system to be used for a particular application. They do however allow the mixing of different earthing systems in the same electrical network. The types of earthing commonly used in industrial applications are given below.

❑ TN: The neutral point is directly earthed and exposed-conductive-parts are connected to that point by a protective conductor.

❑ IT: The neutral point is isolated from earth (or connected through and impedance) and exposed-conductive-parts are earthed independently or to the earthing of the system.

❑ TT: The power system has one point directly earthed, the exposed conductive parts of the installation being connected to earth electrodes electrically independent of the earth electrodes of the power system. The TT system often used for public distribution is normally not used in industrial applications even though it provides a very safe installation and one that is very easy to extend.



Applying IEC to LV installations

TN-S

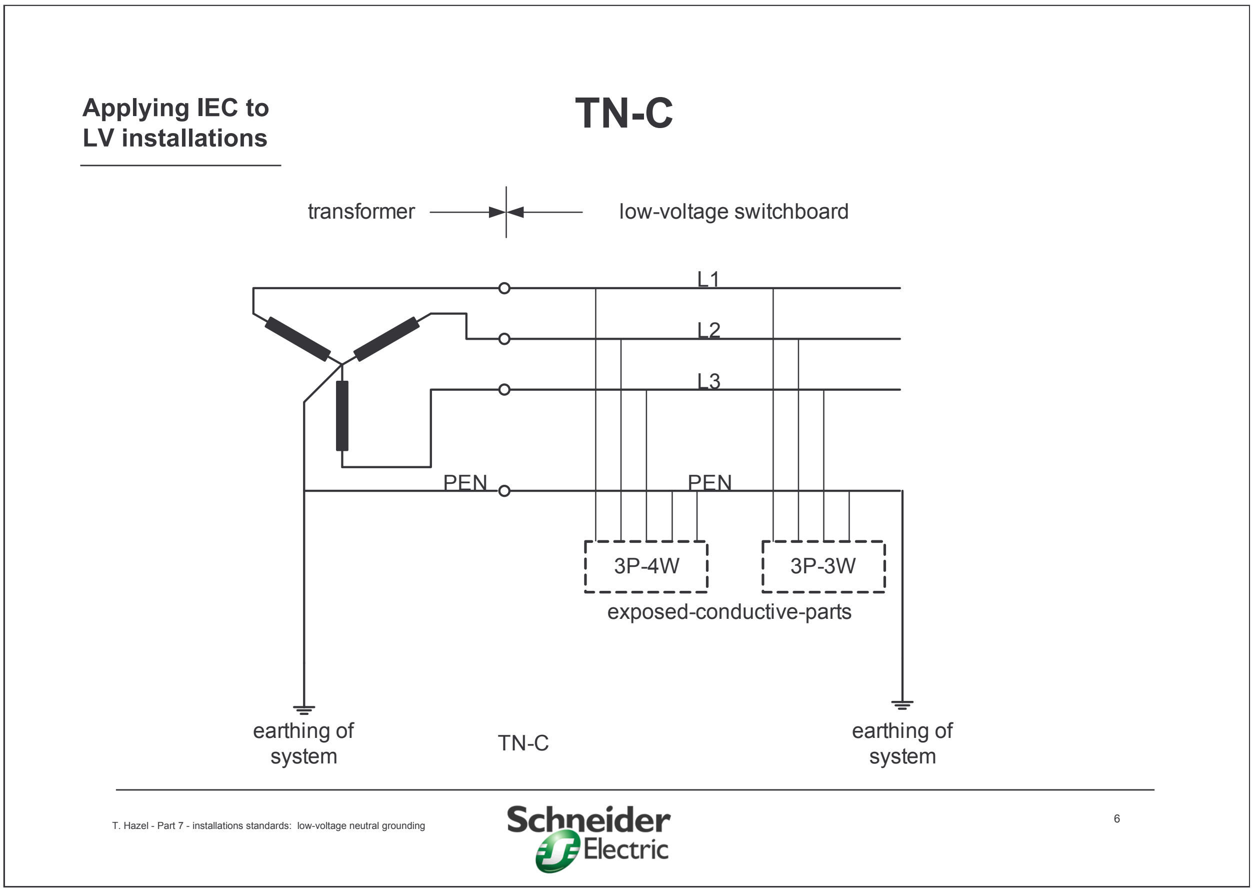
TN systems

In a TN system all phase-to-earth faults result in values of short-circuit current of the same order of magnitude as those produced by phase-to-phase faults due to the direct connection of the exposed-conductive-parts to the neutral point. Since the phase protection devices are used to clear phase-to-earth faults, specific earth-fault protection devices are normally not necessary. This however must be checked by calculations or by measurements at site. Any fault will result in the disconnection of the faulty circuit. TN systems are very common in industrial applications where production losses due to a fault in the distribution system are tolerable.

There are 2 types of TN systems used as described below.

TN-S system

The TN-S system uses a specific neutral conductor (N) and a specific protective conductor (PE). As shown below it is imperative that the neutral conductor N be separated from the combined PE and N conductor (PEN) by means of a link which can be removed to test the insulation of the neutral conductor. A common mistake is placing the link in the protective conductor (PE). The N conductor must not be connected to earth after its creation. It is insulated just as the phase conductors.



Applying IEC to LV installations

TN-C

transformer
low-voltage switchboard
L1
L2
L3
PEN
PEN
3P-4W
3P-3W
exposed-conductive-parts
earthing of system
TN-C
earthing of system

T. Hazel - Part 7 - installations standards: low-voltage neutral grounding

Schneider Electric

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TN-C system

The TN-C combines the protective conductor PE and the neutral conductor N into a single conductor called the PEN. Since this conductor has the function of a protective conductor it must not be switched with the phase conductors. The TN-C system can be used only when the cross-section of the conductors is 10mm² or greater.

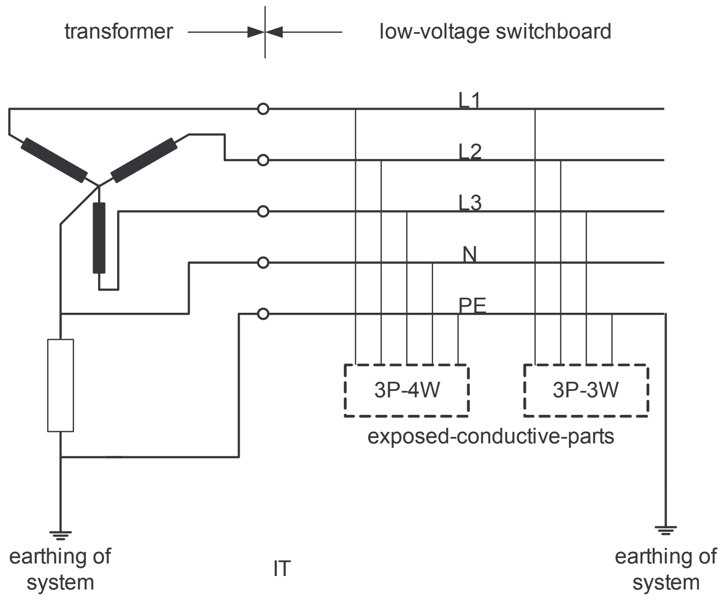
The TN-C system has the advantage of requiring one conductor less than the TN-S system. The 2 major disadvantages of the TN-C system are

☐ the differences in potential of the earthing system at various points due to the flow of unbalanced load current in the PEN

☐ the circulation of earth-fault current in the neutral of the system which can lead to nuisance tripping when there are parallel sources supplying the distribution system.

My recommendation is that TN-C should not be used. Sensitive equipment installed in plants where TN-C is used often have failures due to electromagnetic disturbances flowing through the power system.

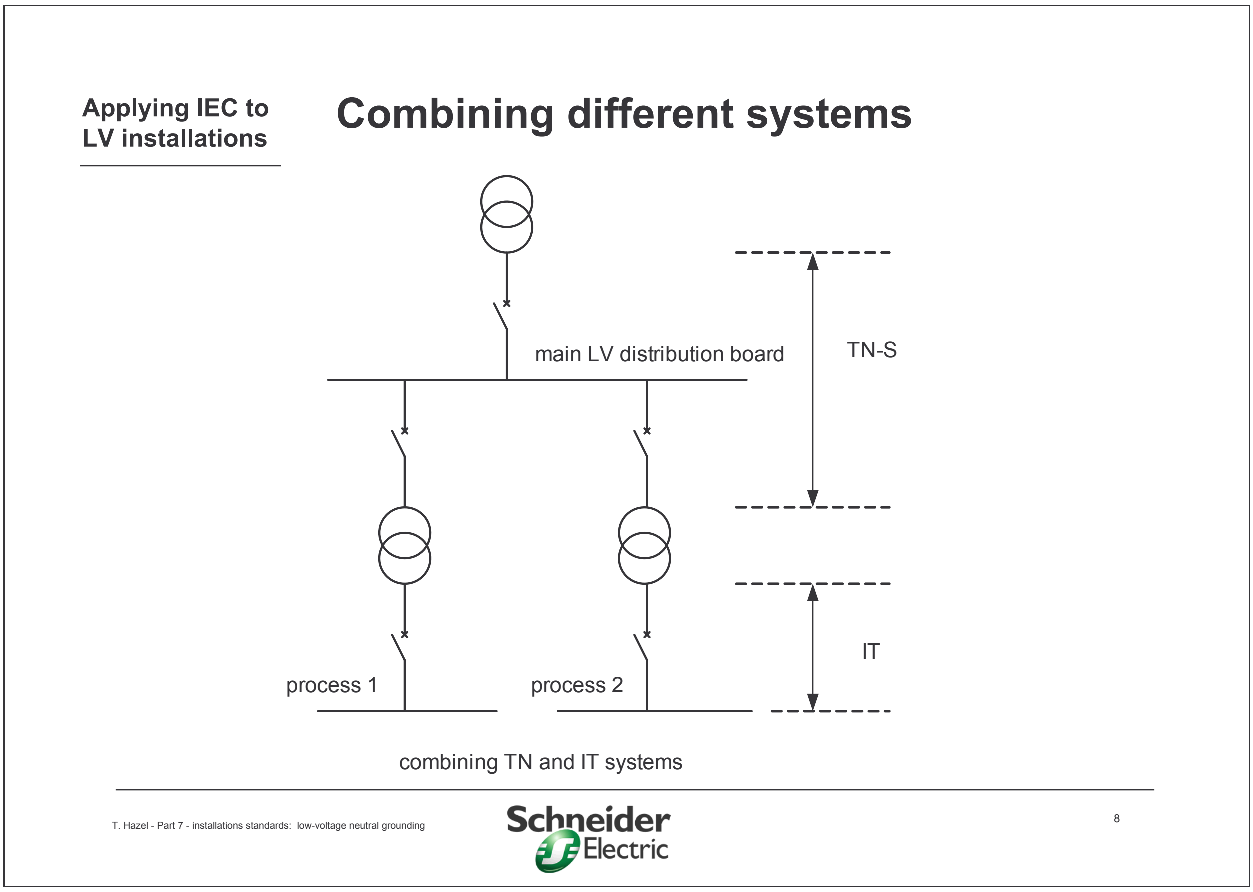
IT



IT system

In the IT system all live parts are isolated from earth or the neutral point is connected to earth through an impedance. This is commonly called high resistance grounding. It is common practice in IEC designed installations to limit the earth-fault current to a value less than 500mA, this value being the maximum earth-fault current allowable in areas where there is a risk of fire. This value is normally suitable for industrial applications since it corresponds to the charging current of 10km of low-voltage cable.

Since the system is not directly connected to earth, the first earth fault will not be dangerous to personnel or equipment and therefore need not be immediately eliminated. This is reason for its popularity in many industrial applications. It is however a requirement that an alarm indicate the fault condition. Maintenance personnel have time to locate the fault and often can eliminate it without interrupting the process. Locating faults is normally done by injecting a low frequency signal between earth and the transformer neutral. Low frequency current will flow through the circuit where the fault is located and can be detected by a hand-held fault locator. Another method is of course simply to open one circuit after the other until the fault has been located. This however defeats the purpose of using an IT system since production losses will occur unless the process has been correctly shut down prior to switching.



Applying IEC to LV installations

Combining different systems

combining TN and IT systems

combining systems

As previously mentioned it is acceptable and often desirable to combine different systems in the same installation. TN-S can be used downstream of TN-C for example. TN-C cannot be used downstream of TN-S however since once the neutral has been split from the PEN it cannot be recombined with it. IT can be used upstream or downstream of TN-C or TN-S since isolating transformers will be required when passing from one system to another.

Since earth faults are less likely in large cables installed in cable trays than in small cables located close to process equipment, the system shown above is often used. The main low-voltage distribution system uses TN-S, and LV/LV transformers provide the isolation necessary for the process parts to use IT. The use of IT for the process reduces down time and since the area covered by each process distribution board is small it is much easier to locate earth faults. TN-S can be used since an earth fault is improbable for the main distribution system. The TN-S portion does not normally need a distributed neutral and therefore a 3-phase 3-wire system can be used saving one conductor in the switchboard and one conductor in the cables.

Special requirements for PE conductors

- never switch PE (or PEN) conductors
- don’t use conduit as a PE conductor
- keep PE & conductors close (low loop impedance)
- connect PE to earth often
- bond metallic structures to PE
- identify PE with yellow-green marking
- design PE cross-section for fault current

protective conductors (PE)

These conductors are very important in any installation since they reduce the risks due to indirect contacts which can be very dangerous. The following guidelines are recommended for industrial applications:

☐ Never switch a PE conductor, or a PEN conductor (PE and N combined in one conductor).

☐ Do not use conduit for a PE.

☐ Install the PE inside the same cable as the other conductors or in the same tray if a separate cable is used. This reduces loop impedance ensuring that earth-fault current will cause the phase protection devices to operate.

☐ Connect the PE to earth wherever possible. When the PE is earthed at a consumer, the touch voltage during a fault will always be small since the exposed-conductive-parts will have the same potential as the surrounding structures.

☐ Bond all metallic structures and connect them to the PE. This reduces the risk of high touch voltages occurring and enhances EMC (discussed in part 8 of the tutorial).

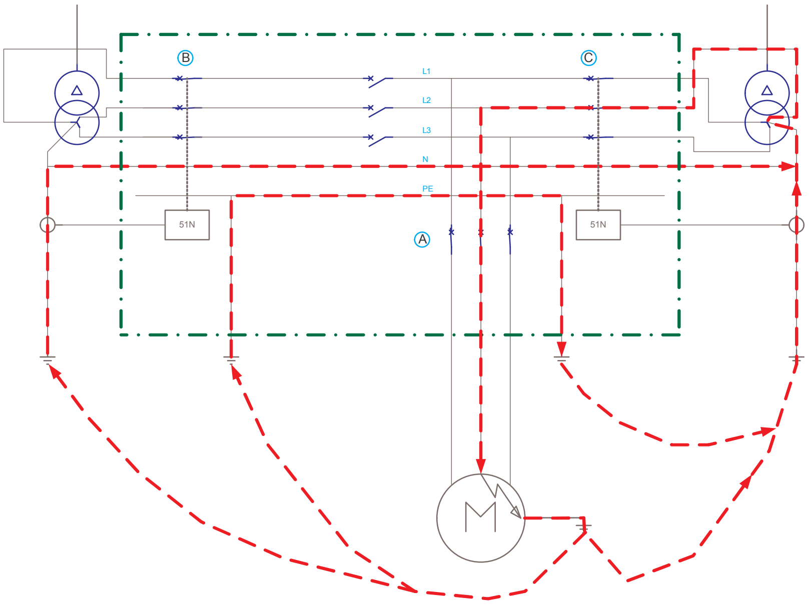
☐ PE conductors should be identified at regular intervals by using green-yellow insulation or marking. Green-yellow is used exclusively for identifying PE conductors.

using 4-pole circuit-breakers

A fails to trip due to fault impedance

Fault current flows through both 51N relays

51N of B acts prior to 51N of C causing blackout



use of 4-pole circuit-breakers in low-voltage switchgear and controlgear

There are 2 main reasons for using 4-pole circuit-breakers

- ☐ safety of maintenance personnel
- ☐ avoiding nuisance tripping of incoming circuit-breakers

safety of maintenance personnel

Neutral conductors are insulated in the same way as phase conductors. The neutral is connected to the PE at the source, directly in TN systems and through an impedance in IT systems. It is therefore possible for the neutral conductor to have a potential which is different than earth. When the neutral is not switched with the phase conductors (i.e. when 3-pole circuit-breakers are used), it is possible to have a high potential between the neutral and earth due to a fault in another part of the system. This can present a danger to the maintenance personnel. In France national regulations require the neutral conductor to be switched with the phase conductors. This is not required by IEC standards.

avoiding nuisance tripping

Double-ended switchboards often have earth-fault protection on the incoming circuits to back up the earth-fault protection on feeders. When the backup earth-fault protection operates, it often trips the incoming circuit-breaker of the busbar section where there was no earth fault instead of the incoming circuit-breaker of the busbar section where there was the earth fault. This results in the loss of both of busbar sections. This incorrect tripping is due to circulation of fault current in the neutral conductor in the switchboard. As shown in the attached sketch this can be prevented by using 4-pole bus-tie circuit-breakers. Earth-fault current cannot circulate in the neutral of the switchboard in such cases. The use of 4-pole circuit-breakers for the incoming circuits has no influence in this case.

When 4-pole bus-tie circuit-breakers are used in a board which is operated with the bus-tie normally closed, the bus-tie is tripped prior to operation of the back-up earth fault protection. This ensures that no earth-fault current will flow in the neutral and guarantee that the correct incoming circuit-breaker is tripped.

Since the PEN conductor cannot be switched, the use of 4-pole circuit-breakers in TN-C systems is not permitted. This often results in nuisance tripping which is one good reason among others not to use TN-C.